in which p, v, and t denote the specific pressure, volume, and absolute temperature of the gas; k is the specific heat at constant volume; a expresses what fraction of total kinetic energy, kt, is progressive; r is the mean distance of the molecules; and R the mean intermolecular attraction; the summation being taken for all possible pairs of molecules.

This investigation depends upon d'Alembert's equation expressing the relation of the force acting to the linear acceleration of the mass moved.

The present paper proceeds to employ Euler's equation, expressing the relation of the couple acting to the angular acceleration of any material body, to find an analogous equation for the mean rotary motion of bodies in a state of stationary rotation. An equation is obtained precisely analogous to that found for progressive motion. But, since the intermolecular attractions cannot accelerate the rotary motion, they do not appear in the equation, which can finally be written in the form

$$a'kt = \tfrac{2}{3}pv \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

in which a' expresses what fraction the mean rotary energy is of the total kinetic energy. Two cases, however, must be excepted from the general equation (2). The first of these is that of molecules which are smooth figures of revolution, such as diatomic molecules may be supposed to be; and the second is that of smooth spheres, such as monatomic molecules may be. In these two cases it is shown that

$$a'kt = pv, \text{ and } a'kt = 0,$$

respectively.

It is further shown, that, in case a variation of state occur, that the variation of the last term in (1) must be always negative, or zero, when the temperature is augmented, as appears from comparisons of the formula with Thomson and Joule's experiments on the free expansion of gases in passing a porous plug, with Andrews's experiments on carbonic-acid gas above the critical temperature, with Berthelot's principle of maximum heat, and with mechanical systems in motion under the control either of gravitation or of elastic forces.

An investigation is then made of the ratio of the specific heat at constant pressure to that at constant volume in imperfect gases; the result of which, for molecules of more than two atoms, may be expressed in an equation of the form

$$k = \tfrac{4}{3} - \tfrac{1}{3}b + \tfrac{1}{6}(5 + i)c \quad . \quad . \quad . \quad . \quad (3)$$

in which k is the ratio of the specific heats in question; b expresses what fraction of the total kinetic energy exists in the form of atomic vibration within the molecule; c, which is very small, expresses what fraction the work done against intermolecular attractions is of the same quantity; and i is the exponent expressing what inverse power of the distance between the molecules may be taken as the approximate law of intermolecular attraction. i is always taken as greater than unity, and usually greater than 3; while the value proposed by Maxwell is 5. The experimental values of k lie between 1.33 and 1.25. If the value of c be assumed to be zero, as it is in perfect gases, then a lies between zero and $\frac{1}{4}$; and, if c is not zero, a must exceed $\frac{1}{4}$ for some of the more complex gases; i.e., the energy of vibration of the atoms within the molecules may exceed one-fourth of the mean kinetic energy of the gas.

In the case, however, in which the molecules consist of but two atoms each, the equation obtained is

$$k = \tfrac{7}{5} - \tfrac{2}{5}b + \tfrac{1}{5}(4 + i)c \quad . \quad . \quad . \quad . \quad (4)$$

in which the value of b must be much smaller than when the number of atoms is larger. The experimental values lie between 1.41 and 1.39; and for air, for which k has been more accurately determined than for other gases, the accepted value is, according to Wüllner, 1.405; in which the influence of the term containing c is perceptible. The value, however, of k, derived from Regnault's most accurate determination of the velocity of sound, is 1.395. For molecules consisting of one atom each, the equation obtained is

$$k = \tfrac{5}{3} - \tfrac{2}{3}b + \tfrac{1}{3}(2 + i)c \quad . \quad . \quad . \quad . \quad (5,$$

The experimental value of k, as found for vapor of mercury (the only known monatomic gas), by Kundt and Warburg, is 1.67.

This ratio has been previously investigated by Boltzmann and by Watson, by the help of generalized co-ordinates expressing the number of degrees of freedom of the system; but it has not been found possible to assume any integral number of degrees of freedom which would cause the value found for k to agree with experimental results. The opinion is expressed by the author, that this method is unsuited to the investigation of this question, because any elastic connection or attractive forces neither allow perfect freedom, nor impose absolute restraints, such as are contemplated by the method.

So far as known, this investigation explains, for the first time, what Watson, on p. 39 of his treatise, regards as "the great difficulty in the establishment of the kinetic theory of gases on the molecular hypothesis."

CONSEQUENCES OF SPLEEN EXTIRPATION.

IN a preliminary notice (*Centralbl. med. wissensch.*, 1882, 900) Winogradow describes the results of spleen extirpation, as manifested in the blood, lymphatic glands, and bone-marrow of dogs, several of which were kept alive in good health for more than two years after the splenotomy.

After the operation the number of red corpuscles in a cubic millimetre of blood always falls in a short time, occasionally within a few days. This diminution is most marked from a hundred and fifty to two hundred days after the splenotomy, when in some cases the red corpuscles are less than half their normal number. Later they become again more abundant. In the first twelve months the size of the red corpuscles is not altered: after that there is found a gradually increasing proportion of abnormally small specimens; and the red corpuscles of exceptionally large size, of which some are always found in normal dog's blood, entirely disappear. The white blood corpuscles show no morphological change; their absolute number is sometimes increased, sometimes diminished.

In one case, a hundred and thirty-two days after the splenotomy, there was found marked enlargement of most of the lymphatic glands. They were much softer than normal, and red on section, especially in the cortical layer, looking much like splenic tissue. This coloration depended mainly on red blood corpuscles which were abundant in the lymph channels of the gland; and was in part due to deposits of brownish-red pigment, which Winogradow ascribes to the detritus of broken-down corpuscles.

The marrow in the central cavity of nearly all the long bones was red-colored, and presented the general appearance of the red marrow of the cancellated bony tissue of young dogs. This color was due to red corpuscles lying outside the blood-vessels in the spaces of the proper marrow tissues.

Later (five hundred and seventeen to seven hundred and sixty days after the spleen removal) similar but less marked divergences from the normal struc-

ture were found in both the lymphatic glands and the bone-marrow.

The blood of a dog which has undergone splenotomy, when transfused into the vessels of another dog, causes in the lymph-glands and bone-marrow phenomena similar to those above described. The author thinks they are in the main due to increased extravasation (? *diapedesis*) of red blood corpuscles.

H. NEWELL MARTIN.

THE CACHAR EARTHQUAKE OF 1869.

THE Geological survey of India publishes in vol. xix., part i., of its memoirs (1882), an account and discussion of the Cachar earthquake of north-eastern India, Jan. 10, 1869. The observations were made and the study begun by the late Dr. Thomas Oldham, then superintendent of the Survey: the work is lately completed by his son, R. D. Oldham, now a member of the geological corps The memoir gives a general account of the shock and its destructive effects; notices of previous descriptions by Oldham, sen., Godwin-Austen, H. F. Blanford, and Archdeacon Pratt, which in the present view seem largely erroneous in their theoretical parts; and a discussion of the position, depth, and shape of the seismic area, and the velocity of the earth-wave's motion and translation. It is well illustrated by photographs, lithographs, diagrams, and maps.

Cachar (or Silchar), where the shock produced great destruction, and after which it was named, is a town on the Barak river, at the southern base of the rainy Jaintia hills, about 300 miles north-east of Calcutta. The seismic vertical was some 80 miles farther north, as determined by thirty-six intersections falling within an area forty miles by four or five; or, excluding the less satisfactory lines, on an area twenty miles by three or four. The depth of the focus is estimated from several tolerably accurate observations at two stations, at thirty miles — or somewhere between twenty-five and thirty-five miles — below the surface. The area over which the shock was felt was an oval measuring 650 miles north-east and south-west, and 400 miles across, covering 250,000 square miles, and including Patna and Hazaribagh on the west; the Ganges delta and Chittagong on the south; the head waters of the Namtonai (branch of Irrawaddy) on the east; and the southern slope of the Himalaya on the north. In the latter direction, the extension of the shock was not determined. Within this, a smaller oval or isoseismal line is drawn to show the region of great destruction; this is symmetrically placed around the seismic centre. The velocity of wave-translations, estimated over a difference of seismic radii of 180 miles,[1] was 1.2 miles a second, which is regarded as very high and improbable, although the observations on which it is based — chronometer time noted by Major Godwin-Austen in the hills forty miles north-east of Cachar, and the clocks stopped by the shock in the surveyor-general's office in Calcutta — seem trustworthy. The wave-motion, even at a distance of eighty-five miles from the seismic vertical, was thirty feet a second; decidedly greater than that found by Mallet for the Neapolitan earthquake of 1857. The large value of the angle of emergence at Cachar is ingeniously accounted for as a result of upward refraction of the wave in passing through the loose alluvial sands. In spite of the violence of the shock, few lives were lost, and few buildings overthrown: the reason being that most of the houses are of wood and bamboo, elastic enough to escape great injury; or, if of masonry or brickwork, the walls are heavy and low, supporting each other against overthrow. A church-tower, a saw-mill, and a two-storied palace were thrown down. A secondary action of the shock produced greater destruction at certain points. The alluvial deposits along the river-bottoms sometimes contain strata of soft, water-logged quicksand; and where the heavy clays overlying these are cut through by the streams, they are often cracked parallel to the steep bank by the earth-wave, and then settle down, and slide on the soft sands beneath. If this happen in a village, the buildings are torn to pieces by the differential motion of their foundations, even if able to escape the effect of the shock. Connected with this effect is the formation of 'sand-craters,' which are shown to result from the wet quicksand being forced up through a vent or crevice opened in the overlying clays; the open cup-like form being produced by the back-flow of the water after the shock passes on. These are finely illustrated, and at once recall the figures given in Lyell's 'Principles' of the 'circular hollows' formed on the Calabrian plains by the earthquake of 1783.

The memoir closes with an appendix giving simple instructions for earthquake observations, and we cordially join the author in the hope that such observations may soon be undertaken at the meteorological stations throughout the earthquake districts of India.

W. M. DAVIS.

[1] There seems to be an error of 100 miles in the distance of Calcutta from the seismic vertical given on p. 84. Correcting this, there would be a difference of 280 miles between the two seismic radii in question, and the velocity of wave-translation would rise to about two miles a second, — even more excessive than is given in the text.

LETTERS TO THE EDITOR.

[*Correspondents are requested to be as brief as possible. The writer's name is in all cases required as proof of good faith.*]

A class-room experiment.

The class experiment commonly employed for demonstrating chemical decomposition consists in heating mercuric oxide, and showing that oxygen is given off while mercury remains behind. An easier and equally beautiful experiment may be performed with crystallized copper formate. This salt, when heated over a gas-flame in a dry test-tube, readily decomposes; oxides of carbon are evolved, and a brilliant residue of metallic copper is left. The formate is easily prepared by boiling copper oxide with formic acid, and filtering. On cooling, fine blue crystals are deposited. Although this experiment involves no new facts, I believe its applicability to class-room purposes has been generally overlooked.

F. W. CLARKE.

Domestic ducks that fly abroad like pigeons.

Facts relating to the history of the domestication of animals are so rare that it is highly important to keep them in view when once they are presented. In this category may be placed O'Donovan's account of the domestic ducks of the Caspian Turcomans. He noticed, especially in the villages bordering upon the south-eastern coast of the Caspian Sea and the Atterex delta, that great flocks of ducks are reared by the inhabitants.

"But so nomadic are the habits of these birds, and so strong are they upon the wing, that it is all but impossible to distinguish them from their wilder brethren that people these solitudes in such vast numbers. I have frequently been astonished at seeing what I took to be a crowd of fifty or sixty mallards come flying into the midst of the village, and, forming in some open space, proceed to march in serried files into the hut devoted